Post-Fukushima Near-Term Task Force Recommendation 7.1

Spent Fuel Pool Instrumentation

This paper describes the industry recommended approach to address the Nuclear Regulatory Commission Near-Term Task Force (NTTF) Recommendation 7.1 relating to spent fuel pool instrumentation. The paper incorporates feedback received from the December 15, 2011 public meeting with the NRC staff and provides an approach to addressing severe events involving the Spent Fuel Pool (SFP) regardless of whether a station blackout (SBO) is involved or whether the event is beyond the design basis. In summary, industry is recommending two channels of SFP level instrumentation, one installed and one portable, with appropriate quality requirements to provide reasonable assurance of availability. Additional details are provided below.

This paper frames the problem to be addressed, the initial conditions at the outset of the event, a conceptual response strategy based on knowledge of pool conditions, a basis for the types of SFP instrumentation needed, as well as a basis for the recommended technical requirements.

The industry has an overall goal of applying the lessons learned from the Fukushima Daiichi accident to enhance the safety of the U.S. reactor fleet by implementing an integrated and effective approach for Near-Term Task Force Tier 1 recommendations (as defined in SECY-11-0137), in a prioritized manner that focuses first on those actions that achieve the most safety benefit.

Problem statement

> *Ensure that nuclear power plant operating crews have the information needed about spent fuel pool conditions during severe events such that they react appropriately to maintain pool temperature and water levels to avoid fuel damage.*

Approach

In dealing with beyond-design-basis events and accident management, the industry has recognized that it is not possible to identify the specific accident progression among a very broad set of potential events. Therefore, it makes little sense to rely entirely on permanently installed fixed equipment and systems that can, by their very nature, be useful in only a limited number of beyond-design-basis scenarios. As a result, the industry has adopted a diverse, redundant, risk-informed and performance-based approach to severe accident management relying on dispersed, portable equipment and flexible guidelines rather than fixed equipment and prescriptive criteria and detailed procedures, so that operating crews can react with flexibility to the symptoms of the events.

As noted in the problem statement, spent fuel pool instrumentation would provide operating crews with the information about spent fuel pool conditions necessary to take appropriate actions to maintain spent fuel pool temperatures and water levels to avoid fuel damage.

As background, on April 25, 2011, the Institute of Nuclear Power Operations (INPO) issued Event Report Level 1 11-2 (IER L1 11-2) that, in part, established requirements for the U.S. fleet to enhance capability to protect SFPs against extreme external events. As part of this IER, operators are required to know the time available until the spent fuel pool reaches 200ºF in the event of a loss of SFP cooling. When this time is less than 72 hours, systems and equipment required to maintain functions for SFP decay heat removal and water inventory control must be protected.

This knowledge of the spent fuel pool heat up rate establishes the initial assumptions and conditions for any severe event that could affect spent fuel pool cooling regardless of whether it is within the design basis or whether an SBO is involved. The time available before reaching 200ºF is based the decay heat of the spent fuel and the water inventory in the spent fuel pool. This time period governs

the prioritization of actions following an undefined severe event. It is, therefore, important to validate the assumption that the undefined event has not in some way caused a loss of inventory. Loss of water inventory will be due to evaporation/SFP boiling as the pool heats up as well as possible sloshing during an earthquake. As long as the fuel remains covered, fuel cooling is assured via evaporative cooling, even if forced cooling is lost due to an SBO event.[1] Typically, a water level of 10 ft. (3 m) above the top of the fuel provides sufficient radiation shielding of the fuel.

An important purpose of the SFP instrumentation associated with NTTF Recommendation 7.1 is to validate the initial conditions in the pool and to take into account a possible SFP inventory loss that would shorten the time available to take actions to maintain SFP level for personnel to operate in the area.

Given that the nature of the severe event is undefined, it is not possible, nor is it desirable to establish a bounding set of design criteria for the design of instrumentation.

Using a symptom-based approach that is independent of the event, if for some reason it is impossible to validate the SFP inventory assumption, then the next prescribed level of actions would be taken. For example, the assumptions regarding SFP inventory would be initially confirmed with installed instrumentation. If the installed instrumentation was affected by the event, the next step would be to either visually verify and/or implement portable monitoring. If this could not be accomplished, because the spent fuel area was inaccessible, then the prescribed action would be based on the presumption that the event had caused a loss of inventory, and makeup actions would immediately be initiated, similar to what is currently envisioned for a major plant damage scenario (10 CFR 50.54(hh)).

Considerations for Developing SFP Instrumentation Requirements

The recommendation for spent fuel pool monitoring instrumentation was developed based on the following considerations:

- Key parameter(s) operating crews need to know to assess, prioritize and guide actions
- Parameters included in NTTF Recommendation 7.1 (e.g., level, radiation, temperature)
- Consideration of existing SFP instrumentation
- Diversity and reliability considerations of SFP instrumentation
- Value of safety-related pedigree for beyond-design-basis events
- Environmental qualifications
- Available instrumentation technology

Parameters

Spent fuel pool water level is the key parameter. A sufficient water level maintains cooling of the fuel and provides radiation shielding. Any actions that would be taken in response to severe events affecting the spent fuel pool would be directed toward restoring level. The frequency of level monitoring is governed by the heat up/evaporation rate (known at the beginning of the event).

[1]It is important to note that a loss of all SFP water inventory does not necessarily translate to fuel damage and a large release of radioactivity. Depending on the circumstances, even if all pool liquid inventory is lost the fuel may be cooled adequately via radiation and convection to steam and air. Moreover, there are provisions for SFP cooling via water addition directly onto the fuel assemblies. However, it is highly desirable to maintain the pool liquid level above the fuel and thereby ensure ample heat removal margin.

Evaporative losses by themselves are slow due to the large thermal inertia of the pool. SFP level is used to confirm the initial assumptions regarding SFP integrity.

Other parameters considered included area radiation and fuel pool temperature. Area radiation provides information regarding access; however this could be provided by portable survey instruments. Fuel pool bulk or surface temperature is not particularly informative, in that the time to heat up is governed the by the decay heat load and water inventory (level). After some hours without forced cooling, the SFP will reach saturation temperature and remain there; from that point onward, the temperature indication provides no useful data. Therefore our recommendation is solely related to level instrumentation.

There is no standard approach or technology for instrumentation currently installed in and around SFPs. Installed level instrumentation typically has a relatively narrow range around normal levels, due to the expectation that pools are maintained nearly full. Some plants rely on visual level indication (e.g., marks on the wall) and adequate inventory is verified routinely during operator rounds. SFP water temperature is typically monitored by thermocouples in the SFP cooling lines. Radiation monitoring is accomplished by area monitors as well as monitors associated with the SFP area ventilation system. The industry proposal to address NTTF recommendation 7.1 is to replace or augment existing installed level instrumentation and to provide a portable and flexible level monitoring capability as a backup.

Reliability and Diversity

Reliability relates to the capability of performing the intended function when needed and performing that function successfully for the mission time. The concept of diversity concerns the ability to withstand common mode or common cause failures. The industry approach addressed reliability and diversity through the use of installed and portable instruments and for instrument power.

Safety-Related Instruments and Power

Recommendation 7.1 as modified by SECY-11-0137 calls for potentially safety-related SFP instrumentation. However, making instrumentation safety-related does not improve safety margins in this instance. At Fukushima, safety systems were lost as a result of beyond-design basis flooding and during the ensuing SBO. "Safety-related" has a specific meaning related to design-basis events. "Safety-related," in the context of NTTF Recommendation 7.1, appears to infer reliability attributes related to seismic and environmental qualification and the application of quality assurance rigor in procurement, design, installation, maintenance and operation. There are many ways of achieving the desired degree of reliability and qualification. Past examples include the application of augmented quality requirements associated with SBO, anticipated transient without shutdown (ATWS) and fire protection. In addition, more recent examples include Regulatory Treatment of Non-Safety Systems in new reactor licensing.

It is important to note that quality requirements for installed devices and portable devices might be different.

Environmental Qualification

The use of portable equipment would be stored such that it is isolated from the environment associated with the initiating event. Both the portable and installed equipment need to be designed to function in the environment that they would encounter during a severe event; an example of this is temperature, humidity and radiation associated with pool evaporation and boiling.

Available Instrumentation Technology

A variety of instrumentation technologies exist that can be rapidly developed and deployed consistent with the recommended approach. The NRC should specify functional performance-based

requirements, permitting utilities to select site-appropriate instrumentation and approaches to address the requirements.

Conclusion and Recommendation

Based on the foregoing discussion, the following attributes for SFP instrumentation address the NTTF Recommendation 7.1

I. System and Components:

- Two channels of level instruments: one installed and one portable.
  - Provides a sufficient range so as to indicate when water addition is needed under all plant configurations.
- Non-safety-related, but with augmented quality requirements that can ensure reliability similar to SBO, ATWS, fire protection.
- Installed channel seismically qualified consistent with the existing plant seismic envelope.
- Environmental qualifications on both channels consistent with expected conditions of operation (e.g., the temperature, humidity and radiation environment associated with the spent fuel pool evaporation/boiling.)
- Power supplies: Installed channel would be powered by a non-safety-related bus with either a back-up battery installed or a portable power source to provide momentary power when needed. The portable channel would be powered by a portable power supply

II. Concept of Operation:

- Assume an event (doesn't matter if design-basis, non-design-basis, nor if an SBO takes place).
- Rely on INPO IER L1-11-2 provisions to provide initial level conditions in pool and knowledge of how long it would take for the SFP to reach 200^{o}F.
- Check level on installed channel.
- If installed channel is working it will confirm initial level conditions or provide a new initial condition (operating crew may need additional information at hand to make such a determination); operating crew then knows when water needs to be added if forced cooling is lost (which may or may not have occurred).
- Place portable level channel in operation as back-up in case installed channel stops operating.
- If installed channel is not working, dispatch personnel to visually look at pool level and place portable level channel in operation. This will provide information to operating crew on when to make the initial water addition to pool.
- If area radiation monitors are not working, use handheld radiation detection device (with appropriate precautions). If radiation levels are acceptable, place portable level detection in place to provide information on when to initiate water addition.
- If handheld radiation detection device shows the pool deck is inaccessible, initiate water addition currently envisioned for a major plant damage scenario (10 CFR 50.54(hh)).